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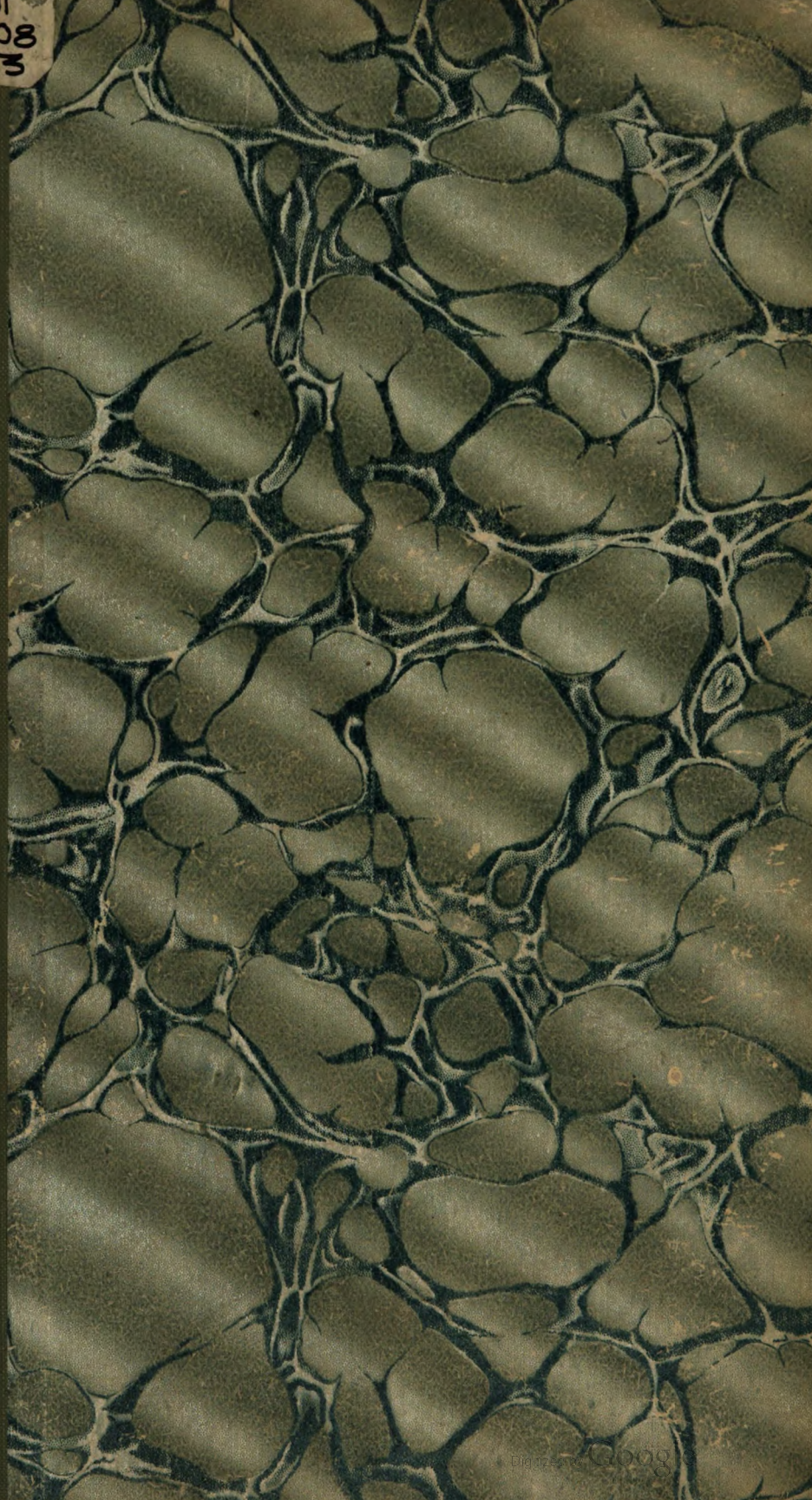
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Barber - Whitehead Torpedo - 1874.

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LECTURE
ON THE
WHITEHEAD TORPEDO.



BY

LIEUT. F. M. BARBER, U. S. NAVY.

1875.

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LECTURE

ON THE

WHITEHEAD TORPEDO.

BY

LIEUT. F. M. BARBER, U. S. NAVY.

U. S. TORPEDO STATION,
Newport, Rhode Island, November 20, 1874.

War 5308.75.3

LECTURE.

Several years ago an officer of the Austrian Marine Artillery conceived the idea of a small torpedo boat floating on the surface, supplied with an engine and boiler for the generation of steam or heated air, by means of petroleum lamps. In the forward part of the boat was to be a large compartment filled with gun-cotton or some other powerful explosive, to be fired by means of a lock and fulminate cap, the trigger consisting of several arms projecting from the bows in various directions, which, on coming in contact with an enemy's vessel, would cause the explosion of the charge.

On the death of this officer, which occurred before he had made any practical experiments with his invention, a quantity of his drawings and papers came into the possession of Captain Luppis, of the Austrian Navy, who being impressed with the importance of the idea, proposed the construction of such a machine, in 1864, to Mr. Robert Whitehead, an Englishman, who was superintendent of a large iron works at Fiume.

The crude idea which I have described was of course impracticable, but it suggested to Mr. Whitehead the idea of constructing an automatic torpedo, which should be capable of running on the surface or at any given depth beneath it, and after years of experiment, and at great cost, he has at length produced the "Whitehead-Luppis Fish Torpedo," or, as it is usually called, the "Whitehead Torpedo," the most widely known and generally adopted of any of the inventions in the field of movable torpedoes.

This remarkable invention, as at present furnished to the different European powers which have purchased the secret, is a vessel of very nearly the shape of a "spindle of revolution," of a length of nearly 14 feet, and a diameter of 14 inches. It is constructed of iron and steel, and carries an exploding charge of 20 lbs. of dynamite. It is driven by a propeller, the motive power being compressed air. Behind the propeller is a rudder capable of regulating the depth at which the torpedo shall go, and also keeping it straight or sending it on any curve which may be desired. The propeller is

surrounded by a ring, and the bow compartment which contains the explosive, can be separated from the body of the torpedo for storage aboard ship in a suitable magazine, and this compartment is provided at its point with an arrow head to stick into the side of a wooden ship. This is all that is positively known of the construction of this torpedo by the public.

The size of the machine does not, however, always correspond to the figures above given. Those experimented with in Fiume in 1868 and 1869 were as follows;

No. 1. Length, 11 feet 7 inches; diameter, 14 inches; weight, 345.8 pounds; charge, 40 lbs. of gun-cotton.

No. 2. Length, 14 feet 1 inch; diameter, 16 inches; weight probably about 650 pounds; charge, 60 lbs. gun-cotton; others of still greater size are said to have since been made.

The velocity of the torpedo changes with the distance which it is required to run, the best results attained with the small torpedo being as follows:

720 English feet, at the rate of 10.5 knots an hour.

1,440 " " " " 9. " "

4,500 " " " " 7.5 " "

This speed can be increased in some of the torpedoes, as one has just been constructed for the German Government, which goes 600 feet at the rate of 17 knots an hour, or a mile at the rate of 10 knots. Of course the torpedo is subject to the action of currents, and this must always be taken into consideration in aiming, the velocity and direction of the disturbing cause being allowed for. Trials made for the British Government in the Medway river, for the French Government at the mouth of the Charente, and for the Italian Government in the canals of Venice, in current varying from one to four miles per hour, are said to have given very good results. Upon touching the object aimed at, at any angle down to three degrees from the longer axis of the torpedo, it explodes with certainty. To prevent danger to the operators, an arrangement is provided which prevents its explosion until it shall have run a certain distance, even though it should strike an intervening substance. It can be set so as to sink to the bottom at the end of its trajectory, and thus prevent danger to one's own ships, and also prevent its falling into the hands of an enemy. It can be set to run to any given distance within its capacity. When used for making

trials it can be made to float on the surface at the end of its run and is thus always recoverable. The same arrangement which provides for the explosion after a certain distance from its launching point is said to furnish a guard to prevent its explosion when the engine stops, and it is desired to be brought to the surface after a run. The torpedo can either be projected from a tube by compressed air, or can be launched by hand by simply starting the engine. The former is the method adopted for use from a ship or submarine battery, and is shown in Plates I and II. (Plate II omitted.) The latter is the plan adopted for use from small boats, and is shown in Plate III.

The launching tube is made of bronze, and is passed through the walls of the battery, or through the dead wood of the stem and stern of a vessel; also, if thought advisable, through its sides, at a depth of from three to twelve feet, according as the draft of the ship will allow. In the submarine battery, Plate II, this tube is provided with a ball and socket-joint, working in a bulk-head, so that it may be trained to bear on a moving object; in vessels as at present fitted the direction is given entirely by the helm.

Plate I represents the launching tube as fitted to the Austrian vessel "Gemse." It is provided at its outer end with a conical door, worked by means of a strap hinge and a lanyard. Inside of the dead wood is a gate working vertically, by means of gearing; the inner end of the tube is also provided with a door fitted like the others, with a water-tight joint; near the inner end of the tube is a branch pipe connecting with a Kingston valve in the bottom of the vessel. The torpedo is first filled with compressed air, by means of an air compressing pump in the engine room, and then set to the depth and to the distance desired, after which the cone containing the charge is secured, and the percussion arrangement properly adjusted. This being done the torpedo is pushed into the launching tube, the door behind it closed, and the water admitted from the Kingston valve into the tube; the vertical gate being raised at the same time. The outside conical door can be raised at any time after opening the Kingston valve and kept open on going into action. The pump in the engine room supplies air to a reservoir placed in some suitable position in the vessel, and when wishing to discharge the torpedo, communication is opened between the reservoir and an apparatus in the rear end of the launching tube, driv-

ing the torpedo out with great velocity, and starting its engine at the same instant.

A launching tube of this description has been fitted to the Austrian gunboats "Gemse" and "Seehund," the British gunboat "Oberon," the French gunboat "Catinat," the Italian gunboat "Tripoli," and the German gunboat "Basilisk."*

In manœuvring it is recommended that the commander of the vessel should use his bow torpedoes for attack and those in the stern for defence, as far as possible. Either of these torpedoes can be fired from a ship while at full speed, or in turning with the helm hard up or hard down. Should the vessel have a higher speed than the torpedo, it will be necessary to alter the course of the ship at the moment of discharging a torpedo from the bow. It is claimed not to be necessary to slow down the vessel, since the torpedo is projected to such a considerable distance ahead that there is no danger of its being overtaken, provided the helm be altered at the moment of discharge. The launching tubes in the side, although apparently of secondary importance, since it is said to be impossible to obtain any accuracy of fire if the vessel is going faster than five or six knots an hour, are still claimed to be of great value in case of the vessel being disabled and an enemy should attempt to ram her; in this case the launching tube would necessarily work in a ball and socket joint in the ship's side, so as to admit of training.

Mr. Whitehead has also plans for a special vessel to be armed solely with his invention, a general idea of which may be drawn from Plate IV, (omitted.) It consists of an iron vessel something on the monitor type, with all the latest improvements, such as water-tight compartments, double bottom. All the exposed portions, both deck and sides, to a distance of several feet under water, are to be heavily plated with iron; a turret, in the middle of the vessel, contains wheel, compass, telegraphs, and bells to the engine room and to every system of launching tubes; also, an arrangement to fire off each torpedo; in fact, everything necessary to put the captain in direct communication with the people below, and to enable him to launch each and every torpedo himself when required. An arrangement of four boilers in the ship, each with its own separate funnel,

* For account of experiments with the "Gemse's" apparatus see Appendix.

permits the placing of sight rods in the centre of the ship and reduces the chance of being disabled by shot; the launching tubes, placed in the ends, are in two tiers, one above the other; those at the sides are either to be in double or single tier, and with or without ball and socket joints. In the forward and after parts of the ship large reservoirs are to be fitted, into which compressed air is pumped by a separate engine and compressing pumps; these reservoirs communicate by pipes with all the launching stations in the battery, and are of such dimensions and strength that the torpedoes can be filled in a moment. All the torpedoes in the vessel are, however, to be charged, if possible, before going into action; the air in the reservoirs only being used for replacing leakages and for projecting the torpedoes from the tubes. The torpedoes can be stowed away alongside the launching tubes or wherever found most convenient; the cone, carrying the explosive, being kept detached and stowed away in a suitable magazine.

For experimental purposes the inventor has at Fiume a wharf running out into the water to a depth of 14 feet. At the end of this wharf is a small receiver, to which a gauge is attached, and from which two flexible tubes are led, one to work the ejector and the other to fill the air chamber of the torpedo; the receiver is connected by a pipe with a large air-compressing pump in a machine shop situated at the foot of the wharf, a launching tube somewhat similar to those used on board ship is suspended from the wharf by means of tackles. The inventor has also several boats similar to those shown in Plate III, for manipulating the torpedoes by hand.

This invention, the principal features and powers of which I have thus generally described, has been successfully kept a secret since its first introduction to notice in 1868. This secret, either with or without the right to manufacture, has been purchased from time to time by different European Governments. Austria leading the way in 1869 by paying a large sum for the secret and conceding the right to manufacture to Mr. Whitehead at the rate of \$600 each for those 11 inches in diameter and \$1,000 each for those 13 inches in diameter. England followed in 1871, paying, it is reported, £15,000 for the secret; still later France, and in 1873 Italy, while still later Germany has also purchased the right, and it is said that Denmark will soon follow. In 1869 Mr. Whitehead offered his invention to our Government for £20,000, and in 1874 it was again offered, but

as yet it has not been deemed advisable to purchase it. In case of the purchase of the secret, the Government so purchasing is immediately put in possession of a proved sample torpedo, with a full set of working drawings. A small number of officers appointed by the Government are sent to Fiume to receive instruction and to be intrusted with the secret, which they are bound by their word of honor not to reveal; the Government is also bound to do all in its power to prevent the secret being discovered. In this way, as has been stated, the secret has remained undivulged, though it would seem that an appeal to the patent laws of most countries would be a greater guarantee of safety to the inventor. Only a few months ago an offer was made to the Chief of the Bureau of Ordnance by a former employee at Woolwich to sell for a moderate sum the secret of the Whitehead torpedo and to furnish working drawings of the same. The offer was, of course, declined; but it serves to show how difficult it is in these days to secure the profits of an invention to its rightful owner without a patent. The Swedish commissioner who witnessed some of the earlier trials of the invention is said to have offered Mr. Whitehead \$10,000 for his secret, saying that it was the opinion of his Government that it would cost about that amount to invent a torpedo of the same description. However true this may be, Mr. Whitehead is said to have spent £40,000 in perfecting his invention; and although it seems incredible that the same invention could not be produced for a much less sum, still the fact remains that whatever the different nations may have attempted in this direction, no fish torpedo, working on the principle of the Whitehead, has yet been produced that will at all compare with it; at least so far as is known to the public.

In 1869 a torpedo of this description was commenced at this station, and in the two succeeding years was so far perfected by the officers then attached here as to produce tolerably fair results. A general idea of its construction may be drawn from Plate V. It is 12 feet long by 13 inches greatest diameter and weighs 480 lbs. It is of the shape of a spindle of revolution and is made of composition; the engine is constructed on the diamond principle and exhausts through the shaft, which is hollow, and carries at its extremity a four-bladed propeller, having two of its blades behind the other two, though at right angles to them. The submerging apparatus consists of a rubber bellows, to the iron head of which is connected,

by suitable rods and bell cranks, a pair of diving rudders; over the head of the bellows is a stout spiral spring. The principle of its operation is as follows: When the torpedo is lying on the surface of the water the bellows lie flat and the rudders are in such a position as to cause the torpedo to dive as soon as it moves ahead. As it passes beneath the surface the pressure of the water raises the head of the bellows against the spring, by which action the rudders are gradually brought to a horizontal position; when they arrive in that position the torpedo should go straight. If, however, its momentum carries it below that plane, the diving rudders are reversed and tend to deflect it up again, and the general result of these alternate deflections being very nearly a uniform motion in a horizontal plane. Adjustments for different depths are easily made by simply altering the length of the diving rudder rod.

No attempt was ever made to apply any lateral steering gear, firing apparatus, or any other of the numerous adjuncts of the Whitehead. The torpedo runs very slowly, and only for a short distance, curving to starboard at the same time, but the submerging apparatus works perfectly.

SUPPOSED PLAN OF ARRANGEMENT OF THE WHITEHEAD.

As before stated, Mr. Whitehead has so far succeeded in keeping the vital portions of his inventions perfectly secret. But from the extent of its reputation and the large number of accounts which have been written concerning its trials, &c., it might be imagined that it would be a very easy matter to give an idea of its general internal construction. The task, however, is one of more than ordinary difficulty, from the utter want of similarity of the various "complete descriptions" which have appeared from time to time in the public prints, particularly since the Woolwich disaster,* and from the discordance in the reports of reliable officers with regard to

* In March, 1874, an explosion of the air-chamber of a Whitehead torpedo occurred at Woolwich, killing and wounding several persons. The explosion was occasioned by the giving way of the head or diaphragm separating it from the remainder of the torpedo. It is said that this diaphragm was not of Mr. Whitehead's manufacture, but was made in England.

even the external appearance of the invention whose trials they have witnessed.*

A careful consideration of all the facts in the case leads one very naturally to conclude that, first, the Whitehead torpedo has been in a state of constant change and improvement since its introduction to the public; and, second, that many of the accounts in the public prints are written with the intention of giving a wrong impression. Such being the case, after adopting some statements as facts, rejecting others as fancies or misstatements, and theorizing on the other requisites which seem to be essential to such an invention, it is believed that Plate VI will give a fair idea of the general appearance of the interior of the Whitehead torpedo. As I consider the essential secret of this torpedo to be in the fact that it is capable of running at a given depth in a straight line, while it is evidently kept at a constant weight during its whole flight, I have only shown what seems to be the best method of accomplishing these different effects in addition to a view of the general division of the torpedo into compartments.

The air reservoir constitutes nearly the whole after half of the torpedo. It is made of steel about three-sixteenths or two-tenths of an inch thick; it is separated from the remainder of the torpedo by a strong bulk-head of the same material; through the centre of the air chamber passes a tube or sleeve, through which passes the shaft; water being freely admitted around the shaft in the sleeve.† The remainder of the torpedo is made of sheet iron, about No. 12,

* Some describe it as very nearly resembling a dolphin, others as resembling a porpoise, others as a long cigar with pointed ends, &c., while all drawings which I have seen, whether the rough wood cuts of an illustrated paper, the more accurate drawings appended to an official report, the sketches of other eye-witnesses, or the necessarily vague outlines given to the torpedo in the tracings generally circulated by Mr. Whitehead himself, all represent it as very nearly resembling the figures generated by the revolution of a circular spindle. The distinction may seem a trifling one at first sight, but the vast difference in facility and cost of mechanical construction in the two cases, as well as the accurate calculation of the volume, surface, &c., to say nothing of the difference in the two cases with regard to displacement, stowage, capacity, &c., are well worthy of note. The position and number of guards or fins, triggers, blades of propeller, mode of projection from launching tube, &c., &c., are all differently stated, though they are matters of minor importance.

† The air chamber is said by some to be cast-steel; by others to be welded; by others to be rivetted with a butt joint; while others say that the whole torpedo is made of wrought iron with the seams brazed.

either rivetted with a butt joint or brazed. Immediately forward of the air chamber most authorities state that a small pair of compound oscillating engines are placed in a compartment to which water is freely admitted. That the engines are of the type described there seems to be little reason to doubt, as they are very convenient, compact, and simple, but that they are in the position stated, I am inclined to doubt for the following reasons: Mr. Whitehead, it is stated, is now using a working pressure of nearly 60 atmospheres or 900 pounds per square inch. An air chamber of the capacity which he uses will weigh when full, at this pressure, something like twenty pounds more than when there is a pressure of but one atmosphere inside of it. The torpedo is also said to float in the water just awash, with the bow a very little light, therefore it would seem that unless the weight of the air was compensated for in some way so as to keep it constant, the torpedo at the end of its course would not only be down by the head, but it would be so much lighter than an equal bulk of water, that any diving rudder arrangement would not control it with the same facility during the whole period. This compensating weight cannot be introduced in the exact place from which the air has escaped, but it can be placed very near it. Apparently the best method of accomplishing this would be to introduce next the bulk-head of the air chamber a compensating water tank, into which water is introduced by a suitably arranged orifice of such size that a pound of water will enter for every pound of air consumed. This orifice is controlled by a valve working with the engine throttle. The air in the tank would be allowed to pass out by an orifice in the top of the torpedo, covered by a valve opening outward. This arrangement, since it is very near the centre of the torpedo, would probably bring it on an even keel at the end of its course with the same draft of water as at first.

The engine, as stated, works in a compartment to which water is freely admitted. This seems to be very desirable, as no lubrication is necessary, and all working parts are kept at the temperature of the surrounding sea water, thus getting rid of the evil effects of the intense cold produced by the rapid expansion of so large an amount of compressed air, both on its own degree of expansion and upon the packing of joints, &c. The engine exhausts freely into the compartment.

Different methods have been suggested for communicating be-

tween whatever diving arrangement is used (which must be forward of the air chamber) and the diving rudders, which are pretty generally known to be at the stern, (although that part of the Whitehead is always carefully concealed.) One plan is similar to that used in the fish torpedo designed at this station, substituting a cylinder and piston for the bellows, and having a rod passing through a second tube in the air chamber, connecting at the rear end of the torpedo with a series of bell cranks, which would pass round the propellor, and connect to the top of a vertical rudder which is to act as a yoke to the diving rudder. Another plan is to have the engine work to eccentrics on the main shaft, which can then be made hollow and have the diving rod pass through it, being geared at the outer end to the transverse or diving rudder alone, the blade of which is divided into two parts, so as to work on each side of the vertical rudder, the latter being merely a bridge or vertical diameter to the ring surrounding the propeller, and capable of being fixed at any angle by set-screws. This arrangement of the vertical rudder corresponds more nearly than any other to what almost all accounts of Whitehead's torpedo state it to be provided with, viz., "a rudder for lateral steering, which is set at such an angle as has been previously determined for every torpedo in order to keep it straight."

The former diving and steering arrangement is open to many objections; the latter would undoubtedly work satisfactorily if the torpedo remained on an even keel. This it could be made to do by an arrangement such that a weight hung like a pendulum or travelling on a transverse rod should be moved to a greater or less distance from the centre of the torpedo, according to the velocity of rotation of the shaft; thus counterbalancing the tendency of the torpedo to list under the action of the propeller; the list being greater or less according as the propeller moves fast or slow, or two propellers revolving in opposite directions might be used, requiring two shafts and considerable gearing. It seems, however, to be simpler to suppose that Mr. Whitehead, after having made the torpedo as stable as possible by the disposition of his fixed ballast, allows it to roll and causes the diving and steering rudders to compensate each other. This idea was suggested by Lieut. Drake, U. S. N., as a means of correcting the erratic course of the fish torpedo at this Station; and as the principle seems to bear a more thorough theoretical research under all circumstances than any other proposed,

an application of it has been shown in Plate VI. The principle is as follows: Since the torpedo will tend to list in exact proportion to the velocity of rotation of the propeller, if this listing tendency be uncompensated, the axis of the diving rudder, instead of remaining horizontal, becomes inclined and acts as a steering rudder, which effect must be compensated for by an additional rudder of a size proportional to the diving rudder placed at right angles to and acting in harmony with it.*

In the application of this principle, shown in Plate VI, both diving and steering rudders communicate with each other by simple gearing placed in a small collar which fits loosely on the end of the shaft abaft the propeller; the lower extremity of the post of the steering rudder is connected by gearing to the end of a rod which passes underneath the torpedo to the submerging arrangement in the central compartment.† The submerging apparatus consists of a small cylinder furnished with a piston, the rod of which is connected, as shown, to a lever of the second order, whose extremity is attached to the rudder rod. The mode of operation of the entire arrangement is as follows: The torpedo being on the surface of the water, the diving rudder will have a small inclination downwards and the steering rudder will be slightly inclined to port; i. e., the torpedo has a starboard helm; the engine being started, the torpedo begins to dive and to list to port at the same time; this list to port inclines the axis of the diving rudder and would cause the torpedo to sheer to starboard were it not for the steering rudder being al-

* In reports of the trials of the Whitehead at Fiume it is stated that sluering the launching tube had no effect on the trajectory of the torpedo; hence it was concluded that where a launching tube was fitted in the bow of a vessel a rolling motion would not affect the accuracy of fire. The principle here suggested is the only one that has come within my knowledge that is theoretically capable of enduring such a test, provided the torpedo slues when the launching tube does.

† Accompanying the account of the accident at Woolwich which appeared in *The Engineer* shortly afterward, was a drawing of the fractured diaphragm, which had formerly separated the compressed air reservoir from the remainder of the torpedo. This drawing showed only two holes in the diaphragm, one for the shaft and one for the tube conveying the compressed air to the engine. The "complete description" of the "secret," as given in "*The Engineer*," was as improbable as all others have been that have come within my notice; but, considering the appearance of the diaphragm, the statement that a rudder rod passes underneath the torpedo would seem to be correct, at least in the case of the torpedo which burst.

ready so adjusted as to compensate for it. As the torpedo approaches the depth for which it is set, the water, acting on the piston in the diving cylinder and forcing it down, draws the rudder rod forward, and both rudders become more nearly straight, which is just what is required, since the diving rudder, not being not so much deflected, the same list of the torpedo does not cause it to act so much like a lateral rudder as it did before. At the depth for which the torpedo is set both rudders will be straight—*i. e.*, amidships—below that depth the diving rudder is inclined upwards, which, with the port list, would cause the torpedo to deviate to port were it not for the steering rudder, which by this time carries a port helm and keeps the torpedo straight.

The adjustment of the apparatus for different depths depends upon the interior arrangement of the submerging cylinder. If the piston is made tight-fitting and the air within the cylinder used as a cushion, then, to change the depth at which the torpedo is to run, the rudder rod must be disconnected from the lever, a small valve in the side of the cylinder opened while the torpedo is out of water, and the piston moved in or out according as the torpedo is to work at a greater or less depth than before; the valve in the side of the cylinder is then closed and the lever secured to the rudder rod in this new position. If, however, the cylinder be made of such length that the compression of the air need not be taken into account, or if a communication be opened between it and the compartment of the torpedo forward of it, which would have practically the same effect, a spiral spring may be inserted underneath the piston. The piston itself, being fitted loosely into the cylinder by means of folds of rubber cloth—*i. e.*, bellows fashion—will have a water-tight movement in and out, and is capable of being adjusted in two different ways: First, by disconnecting the lever from the rudder rod and moving the rod forward or aft a known distance and reattaching it to the lever; second, by disconnecting the rod from the lever, altering the tension of the spring, by means of a thumb nut, and reattaching the rod in the new position of the lever. The latter arrangement would probably be the better, as the rudders would always have the same amount of motion; but either adjustment can be made while the torpedo is in the water.

As before stated, the engine works in a compartment to which water is freely admitted, and the submerging cylinder is probably

in the same compartment, having forward of it a tight bulkhead, which separates this part from the remainder of the torpedo. Of this remainder we know that the forward part or point of the torpedo constitutes the shell containing the exploding charge, which is removable from the body of the torpedo; this, then, simply leaves a compartment between that of the charge and that of the engine and submerging cylinder, whose contents is unaccounted for, and it seems very likely that its principal object is to give buoyancy to the torpedo.

It does not seem to be necessary to attempt any detailed description of the external attachments of the Whitehead, nor of the other arrangements which enable it to accomplish what are necessarily its secondary functions. The bow is probably supplied with some trigger arrangements for setting in action a percussion fuze, which fires the charge. The forward portion of the torpedo also has guards to steady it in a launching tube, and a ring is placed round the propeller, from which guards run forward to the body of the torpedo. Such an arrangement is necessary for keeping weeds from the propeller and for attaching the rudders. Some sort of starting trigger is also supplied, which may be put in action by hand or when the torpedo is driven from its tube. As regards what are characterized as the secondary internal arrangements, all the detail in regard to them would undoubtedly be left in actual practice until the fish had been so far completed as to enable it to perform satisfactorily its most important functions, viz: accuracy, speed, and constancy of depth of immersion. This having been accomplished, the relative position of the necessary parts would determine the space to be occupied by the secondary arrangements, which would materially affect their nature, as there are almost always several ways of accomplishing the same object. A way might be suggested for accomplishing each of the secondary considerations, although the actual method for each might not be the one adopted when that portion of the problem came up for practical solution. Suppose, then, that the propeller shaft be prolonged beyond the engine crank and furnished with numerous gears, a variety of objects could then be attained; for instance, the torpedo might be made sensitive only after running a short distance by having a rod passing from the engine compartment through a tube reaching to the fuze arrangement in the shell containing the exploding charge. This rod has its forward extrem-

ity forked, the tines passing on each side of a cross bar and resting in the normal position of the rod against a shoulder on the percussion plunger, and thus preventing any movement. Suppose the after end of this rod to be connected with a worm gear on the shaft. Obviously, then, the action of the worm gear would be to cause the gradual withdrawal of the forked rod from the shoulders of the percussion plunger as soon as the engine was started. Any given number of revolutions would withdraw the rod far enough to enable the percussion arrangement to strike the transverse bar by contact of the triggers of the torpedo with any obstacle, thus causing the explosion of the charge, and, by having the worm gear short, it would run itself out as soon as it had accomplished its object. When experimenting with the torpedo, the worm gear is simply thrown out of adjustment, when, of course, the forked rod is not withdrawn at all, and the torpedo cannot be exploded by contact. To make the torpedo sink or rise at the end of its run, it is only necessary to have the compensating water tank a little larger and divided into two parts by a diaphragm. This diaphragm should have a hole in it, which can be closed at pleasure. By having this hole open, enough water will run into the tank after the torpedo has finished its trajectory to sink it in a very few seconds; by leaving this hole closed, only so much water will enter the tank as is equal to the weight of compressed air used, and the torpedo will rise to the surface when the engine stops.

To set the torpedo to run at any given speed, a small reducer, located between the cylinders, receives the full pressure of the compressed air as soon as the throttle is opened, but only allows it to pass to the engine at a given number of pounds per square inch. The rapidity with which the air is allowed to pass from the reducer to the engine regulates the speed of the torpedo.* To set the torpedo to run on any curve, the gears between the rudders may be altered one or more teeth, according as a small or great curve is

* A description of such a reducer will be given in the latter part of this lecture. A variety of contrivances of this sort have been devised, but it is merely necessary to mention at this point that the principle involved in almost all of them, is to so utilize the pressure of the air itself as to enable the reducer to close the orifice by which it receives the full pressure from the reservoir, whenever such pressure amounts to more than a given sum. The delivery from the reducer to the engine is therefore constant at whatever pressure it may be set to work at.

desired. To set the torpedo to run to any given distance, and then to stop, it is merely necessary to have a supplementary valve in the supply pipe between the throttle and the engine. This valve can be controlled by a powerful spring, which shuts the valve when not held back by a pawl. This pawl can be liberated by the pressure against it of an arm traveling on a small rod. The arm can receive its motion by means of a worm gear on a small countershaft parallel to the rod, the countershaft itself receiving a slow motion from the main shaft. Such an arrangement as this can be made to operate so that the air can be shut off from the engine at any time by simply putting the arm into gear with the worm at a known distance from the pawl. When the engine starts the arm begins to move towards the pawl, and by the time the torpedo has traveled the required distance, it comes in contact with it and pressing it so as to liberate the spring, closes the valve and thus shuts off the air from the engine, causing the torpedo to stop. Other arrangements to accomplish the same object might be adopted, in which the pressure of the air itself may be used to close the valve after the lapse of any required time, but, as before stated, the arrangements actually adopted in this and all other secondary cases would depend much upon the position of the other arrangements for accomplishing the primary object.

In the plate a four-bladed propeller is represented, but the accounts vary as to whether the Whitehead has a propeller of three or four or six blades, probably some have the one and some the other. The problem of propulsion in this case is very peculiar. The torpedo has an exceptionally clean run; the propeller can have a diameter almost equal to the greatest cross section of the torpedo, and, moreover, it can be very rapidly revolved, but at such a distance below the surface as to insure a solid volume of water to work in.*

The advantages of the general arrangement of weights, compartments, &c., which have been assigned to the fish-torpedo, as constructed by Mr. Whitehead, may be summed up in a few words. All parts of the torpedo may be made perfectly water tight, except the central compartment, and these water-tight joints need never be

* In the plate the stem of the torpedo should be considerably smaller and the hub of the propeller be of nearly the same size as the stern, so that it and the rudder collar abaft it would form a prolongation of the taper of the after body of the torpedo.

broken, a fact whose importance cannot be overestimated. The central compartment to which water is freely admitted can be made easily accessible by large hand-holes; in this compartment *are all* the adjustable parts, except those which are on the *outside* of the torpedo. The water compartment being in the center of the torpedo, the two ends can be more easily balance about this point than if it were in any other position.

Supposing the above description to give a fair idea of the actual construction of the Whitehead torpedo as it now stands before the world, it would seem possible to improve it as a weapon for harbor defense by the introduction of an electrical binnacle arrangement which shall cause it to steer a compass course.* This idea for controlling the helm has been frequently suggested, and for illustration a description is given in the appendix of such, an arrangement proposed by Gunner Burdett to be applied to the fish torpedo at this station. Such an apparatus could be applied to the torpedo now under consideration, by having the whole of the torpedo forward of the compressed air reservoir made of copper or composition, and prolonging the shaft into the compartment forward of the engine-room, so as to place its necessary attachments, as well as the binnacle and battery, in that compartment, the electric rudder being in the guard directly underneath this part of the torpedo. In this case, the compensating rudder geared to the diving rudder at the stern could be done away with entirely, since the electric rudder is so arranged as to come into action whenever the torpedo deviates from a given compass course, and consequently the torpedo must steer that course whether it lists or not. The magnetic influence of the steel air reservoir on the compass can be completely neutralized by compensating magnets placed abaft the compass. It is plain that a fish torpedo steered in this manner would go very nearly straight across a harbor at any stage of the tide, (!) or at least it would go straighter than by any merely mechanical arrangement, though even with these as stated in the early part of this lecture, Mr. Whitehead is said to have obtained remarkable results.

* This notion is, in my opinion, of no practical value.—W. N. J.

PLANS FOR FISH TORPEDO SUBMITTED TO BUREAU OF ORDNANCE,
JUNE 1ST, 1874.

Since 1871, various suggestions have been made and something has been done with regard to a new fish torpedo at this station; but no plan was regularly submitted to the Bureau till June, of this year. The general idea which was originally intended to control the construction of this proposed fish was to approximate as closely as possible to what was supposed to be the plan of the Whitehead, unfortunately, however, the prominent steel firms of this country, one and all, declined even attempting the construction of an air reservoir of the requisite shape and dimensions which would endure the necessary strain, and it consequently became necessary to alter the entire plan of the torpedo. The necessity of constructing the air chamber of a metal of less tenacity than steel and at the same time of a capacity such that the torpedo should have a range equal to Whitehead's, rendered it necessary that it should constitute the middle section. (Plate VII, Fig. 1.) This weight and position not only diminishes the size of the exploding charge but effects the facility of manipulation of the engine and submerging and steering apparatus, (the principal parts liable to get out of order,) since they cannot be placed together in the middle of the torpedo in a compartment to which the water is admitted; these objections led to the consideration of a second plan, Plate VII, Fig. 2, in which they are partially obviated by the use of carbonic acid gas as the motor whereby the charge and range are very much increased, and the torpedo made more stable, since the weight of the chamber and gas are in the bottom; the principal objection to the use of the gas is, that after having made one run the gas chamber must be taken out of the torpedo to recharge it or insert another one, thus necessitating the breaking of water-tight joints, &c.; the gas chamber is, however, much smaller, and consequently easier to construct and cheaper than an air chamber. For the construction of each of these chambers two plans were submitted. For the air chamber, first, to deposit it of pure copper by electricity, which can be done for about one dollar and twenty-five cents a pound; second, to have it cast from the best of gun-metal or phosphor-bronze, using a long sinking head; in either case having a reasonable amount of eccentricity in the shape of a keelson piece or some similar arrangement to increase

the stability of the torpedo. For the gas chamber it was proposed: first, to deposit it of pure copper by electricity; second, to have it made of wrought-iron with the heads to screw in, and having a stay-bolt passing through both heads.

In both plans submitted the exterior dimensions were the same; the internal arrangements, however, being somewhat different, it was considered advisable to submit detailed plans of both with drawings, (Plate VII, Figs. 1 and 2,) in which the dimensions of the different parts represented are very nearly on scale, though some of them, such as size of rudders, &c., it would be impossible to determine, except by experiment.

The plan represented in Fig. 1 may be thus described: torpedo, 12 feet 8 inches long; greatest diameter, 16 inches; shape very nearly that of a "spindle of revolution;" total cubic contents 9.326 cubic feet; total displacement, 598 lbs.

The forward compartment contains the explosive; it is to be made of No. 14 copper, shaped on a former and the seams brazed; it will screw on to the end of the air chamber. The surface of this compartment is 10.19 square feet, and when made of No. 14 copper will weigh 29.6 pounds. The charge of explosive will be from 75 to 160 pounds, according to the weight of the air chamber and machinery, and is to be exploded by a plunger acting on a percussion primer or by other suitable means.

The air chamber, constituting a section of the torpedo, is 46.7 inches long, and if made of gun-metal bronze of an average thickness of three-eighths of an inch, will weigh 269 pounds, and have an internal volume of 4.44 cubic feet. At a pressure of 900 pounds per square inch it will contain 266.4 cubic feet = 20 pounds of air. Estimating good gun metal bronze to have a tensile strength of at least 40,000 pounds per square inch, the air chamber will bear a bursting strain of 1,970 lbs. per square inch. If deposited of pure copper one-half an inch thick, the air chamber will weigh 364 lbs., and have an internal volume of 4.217 cubic feet = 196 lbs. of air, at 900 lbs. per square inch. Estimating the tensile strength of deposited copper to be 34,000 lbs. per square inch, this air chamber will bear a bursting strain of 2,262 lbs. per square inch.

The shell of the torpedo abaft the air chamber is made of No. 14 copper, and screws on to the rear end of the air chamber; its surface is 12.92 square feet, and it weighs 37.5 lbs; it contains the

compensating tank, the engine and shaft, and the submerging and steering apparatus. The compensating tank is a copper vessel of suitable shape and size, which fits in immediately abaft the air chamber. It is provided with a valve which is opened at the same time as the engine throttle, allowing the sea water to enter the tank just in proportion as the air chamber becomes lightened by the consumption of the air. The air in the tank passes out through a valve opening outward in the top of the torpedo.

Immediately abaft the compensating tank is the starting throttle. This is so adjusted that by knocking down a suitably arranged lever on the top of the torpedo the compressed air is admitted at its full force from the air reservoir to the reducer of the engine. It also admits air at the same time to the small cylinder shown in the bottom of the torpedo, to the piston rod of which is attached the stem of the valve which admits water into the compensating tank.

The engine (not on scale in the plate) is a three-cylinder Brotherhood, and occupies a compartment separated by air-tight diaphragms from the remainder of the torpedo. To facilitate the manipulation of the different parts it will probably be found advisable to make a joint in the shell of the torpedo at this point, to be reinforced and packed tight by means of a rubber gland and thumb-screws, to be set up through a hand hole in the shell. The exhaust takes place directly into the engine room and finds its way out through a hole in the bottom of the compartment, provided with a valve opening outward, or, if desirable, the water may be freely admitted.* The engine is supplied with a reducer, placed directly underneath the engine, and shown at full size in Plate VIII, (omitted.) By this arrangement the air from the reservoir, after passing the throttle-valve, enters through the pipe C and around the valve B into a chamber, one of whose sides consists of a curved sheet of metal, to

* In the Scientific American of October 3d, 1874, appeared an account given by Mr. Brotherhood before the British Institution of Mechanical Engineers of his three-cylinder engines as used for working the Whitehead fish torpedo. "This had three cylinders, each $1\frac{3}{8}$ inches by $1\frac{1}{2}$ inches stroke, driven by a pressure of 450 lbs. per square inch, admitted through a reducing valve from a reservoir of air stored at 900 lbs. per square inch. This engine had run at 2,225 revolutions per minute, developing $2\frac{1}{2}$ horse-power, or .28-horse power for each pound of its weight." It was decided at this Station to adopt the Brotherhood engine for our proposed fish torpedo as early as March, 1874, and it is gratifying to observe that they are now apparently making experiments in the same direction in England.

which is tightly secured the stem of the valve B. From this chamber the air passes through the pipe A to the engine. The supply of air to the engine is regulated by the position of the valve B, whose stem passes through the bottom of the torpedo, so that it can be adjusted from the outside. The action of the air on the curved side of the chamber springs it outward whenever a given pressure is surpassed, the effect of which is to close the valve B until the overpressure is relieved and the curved side comes back to its original position and opens B again. The practical effect of the arrangement is to feed a constant pressure to the engine, no matter how high or how variable may be the pressure in the air reservoir.

The submerging and steering apparatus, Plate VIII, [omitted,] is the same in principle as the one shown in Plate VI; but its application is somewhat different, since it is here located in the stern of the torpedo, a change rendered desirable by the fact that in any other position a rudder rod passing outside the torpedo would not have a fair lead. It consists of a cylinder six inches in diameter and of such a length that the distance between the lower side of the piston and the bottom of the cylinder is six inches. This cylinder is placed around the shaft in the position shown. The shaft passes through a stuffing-box in the forward end of the cylinder and through a stuffing-box in the piston. From this point aft the shaft is hollow, and just abaft this point it is slotted for a short distance. A rod works through this hollow portion of the shaft, and is connected with it by a pin passing through the slot; this pin revolves in a suitable hollow in the piston, so that it is free to rotate within it and at the same time has motion of translation with it. The after end of the rod projects beyond the propeller, and is connected with the rudder through a collar by means of a rack and small gears. The collar is connected with the shaft by a pin on the latter, working in a score in the former, so as to have no motion of rotation or translation, while the rudder rod revolves freely within it, as it also does in its connection with the rack. The forward end of the cylinder constitutes a water-tight bulkhead, which separates this portion of the torpedo, to which water is freely admitted, from the remainder. The mode of operation of this apparatus is the same as that already described. Fore and aft motion is communicated to the rudder rod by the pressure of the water on the piston, and by means of the rack and gears the proper motion is given to the rudders. The rudder

rod has a motion of three-quarters of an inch to bring the torpedo to its proper depth, and the apparatus can be set for a depth of eight, twelve, or sixteen feet. This adjustment is effected by opening a valve, shown in the side of the cylinder, when the torpedo is out of water and changing the length of the cylinder by unscrewing the cap on the piston, taking out the pin, sliding the piston in or out of the cylinder, putting the pin through the proper hole in the rod, screwing on the cap, and closing the valve. Only three adjustments are allowed for, as it is considered that this number would be found sufficient for all practical purposes.*

The rudders are each constructed in two parts, both of which work simultaneously; they are intended to be made of thin brass, and are balanced. The inner bearing of all the rudders is the collar before described as connected to the shaft, and through this the rudder rod works; the rack and gears being on the outside of the collar.

The plan represented in Plate VII, Fig. 2, may be described as follows: Torpedo 12 feet 8 inches long, exclusive of propeller; greatest diameter 16 inches; shape very nearly that of a spindle of revolution; total cubic contents 9.326 cubic feet; total displacement 598 lbs.

The entire shell of the boat is to be made of No. 14 copper in three sections, shaped on a former and the seams brazed; the sections of the torpedo are to be connected together by reinforcing them at the point of junction by an annular ring; a rubber gland is placed between the rings of the two sections to be connected, and the joint made tight by thumbscrews working through holes and slots in the rings on the inside. Total surface of shell 36.896 square feet; total weight of shell made of No. 14 copper, 107 lbs. The forward section contains the explosive, the charge of which will be from 180 to 210 lbs. according to the weight of the gas chamber and machinery; the gas chamber occupies the position shown, and is 10 inches in diameter and 13 inches long (inside measurement)

* The remarks made concerning a bellows head and spring in describing the arrangement in Plate VI, apply equally here, and from experience obtained since June 1st, with several small pneumatic cylinders of brass with tightly fitting pistons which had been in store for several months, and which were found to have become so gummed in the packing, and corroded by salt air as to be almost useless, it seems highly probable that, for permanency, the bellows arrangement would prove most reliable.

with hemispherical ends additional, making a total external length of 24.5 inches; if made of three-quarter inch ($\frac{3}{4}$) wrought-iron it will weigh 167 lbs. and have a capacity of 1544.6 cubic inches. It will contain 46 lbs. of liquid carbonic acid gas at a temperature of 80° Fah. = 371.3 cubic feet. If the gas chamber is made of deposited copper of the same thickness, it will weigh 191 lbs.; estimating the tensile strength of both copper and wrought-iron at 34,000 lbs. per square inch, the gas chamber will bear a bursting strain of 4,710 lbs. per square inch; the pressure of the gas is—

690	lbs.	per square inch	at 42°	Fah.
855	"	"	60°	"
1200	"	"	86°	"

More liquid gas could be put into the chamber; but as the liquid itself expands three-tenths (.3) of its volume between —4° and +86° Fah. it would not be safe to force in more than 46 lbs.

The compensating tanks consist of two suitably shaped copper vessels each capable of containing 23 lbs. of sea water, one placed forward and the other abaft the gas chamber; these tanks have rubber connections on their pipes so as to facilitate their removal when the gas chamber is to be taken out. The object of these tanks is to compensate in weight for the consumption of the gas, and the valve gear is arranged as previously described. All other parts of the torpedo are similar to those already described in Fig. 1; but in working with carbonic acid gas, there would probably be a still greater necessity for allowing free entrance of the sea water to the engine compartment to keep up temperature.

In projecting the torpedo from a launching tube it is intended to support the torpedo by means of a sabot made in sections, and fitting round the shell forward of the propeller ring; the compressed air being admitted to the rear of the tube drives out the sabot, carrying the torpedo with it, the sabot falling away as soon as it is clear of the tube.

CALCULATION OF ENGINE AND PROPELLER FOR FISH TORPEDO.

Since the above described plans were submitted to the Bureau, I have made a series of experiments with reference to the calculation of the various dimensions of the engine and propeller necessary to drive the torpedo at any reasonable speed. These experiments con-

sisted in ascertaining the power actually expended in pulling a body of this shape through the water. The shell of the fish torpedo now at this station was divested of its propeller and the diving apparatus was adjusted for a depth of eight feet. A piece of nine-thread rat-line stuff, long enough to have 100 feet of it constantly in the water, was attached to a shackle in the bow of the torpedo; the other end of the towline was secured to the hook of a spring scales, the ring of the scales being made fast to the stern of the steam launch. The torpedo was then towed at different velocities up to nearly eight knots an hour, (the fastest speed obtainable with the towing launch,) and the position of the scale-pointer carefully noted. The torpedo was then cast off, and a separate set of results obtained with the towline alone. These two sets of results being then plotted, gave the curves shown in Plate IX, [omitted,] both curves being drawn through the points indicating the highest pulls obtained on successive days for the same velocities. The result appears extraordinary in view of the law governing the passage of ordinary vessels through the water, where the power required is said to vary as the cube of the velocity. Here the power required not only does not follow this law, as shown by the direction of the curve, but a curve of double flexure is actually indicated at a speed below eight knots. The lower curve (that of the rope alone) being evidently a simple parabola, has been plotted, as indicated by the dotted prolongation, from a speed of about eight knots up to twenty, by means of its equation. The upper curve has its lower portion rather incorrect, from the fact that the towing launch gave a velocity of over one knot per hour, while towing the torpedo at the lowest possible speed that enabled the engine to pass its centre, but the middle and upper portion of the curve would indicate that not only was the small pull of 38 lbs. all that was actually required to drag the torpedo at a speed of nearly eight knots, but that a comparatively small increase of this pull would have given it a speed of twenty knots.

The absence of any data concerning similar experiments of this nature renders it impossible to make a comparison of my results, but in Bourne's Treatise on the Screw Propeller, published in 1867, he mentions the fact (page 202) that a spindle of revolution, of about the proportions used in this case, represents a solid which corresponds exactly to a model with rectangular sections of corresponding area, constructed with perfect parabolic lines, and therefore

displaces water at the same rate. The parabolic body of rectangular section having been previously described as that which will pass through the water with the least resistance, and on page 206 he also says: "It appears probable, moreover, that in case of high speeds maintained by very sharp vessels, the resistance will only increase up to a certain point and will then remain stationary or increase very slowly. For in well-formed vessels nearly the whole resistance is caused by the friction of the water upon the bottom, which causes a stratum of water to adhere, but at high velocities instead of adhering, the water may be torn off, and the resistance may be materially affected thereby."

Now, in this case we have an exceedingly well-formed vessel, and since it is constructed of polished metal without an obstruction of any kind upon its surface, it seems plausible to suppose that the probable tearing off of the water may take place at a much lower velocity than would be possible for any ordinary description of vessel.*

The apparent facility with which Mr. Whitehead has lately increased the speed of his torpedoes, would also seem to indicate that it has been less difficult to accomplish than was at first supposed; his first productions averaged from five to seven knots per hour and it was not until 1871 that he produced one for the English Government that would make over ten knots per hour for any great distance. At the request of the German Government, however, for a torpedo that would make fifteen knots per hour for 500 feet, he suddenly produces one that is capable of making seventeen knots per hour for 600 feet, and it is said to be but little larger than his old ones.

The pressure is higher than he at first used, but it is believed not to exceed 900 pounds per square inch, and merely increasing the pressure to this amount would not account for the vast increase of

* At about the same date as the preceding trials some rough experiments were made with towing a cylindrical vessel 11 feet long and 1 foot in diameter, having one end pointed and the other end square, weighing 460 lbs., the outer surface being rough, with two projecting lugs on the upper side, and the vessel floating with its upper side just awash. The results would seem to indicate that if a fish torpedo were made cylindrical with pointed ends, and had its surface rendered perfectly smooth, it would require more power to drive it at a low speed than would be required for a spindle of revolution, but at very high speeds the power required would not materially differ. Should further experiments prove these indications to be correct the fact would be of great importance as regards the facility of construction and capacity of movable torpedoes of this nature.

speed. It would seem that the resistance encountered at speeds above ten or twelve knots was less than had been anticipated, and once having been able to get over the point of contrary flexure in the curve of resistance the higher velocities were more easily attained. If the foregoing reasoning be correct it is fair to assume that Mr. Whitehead will yet produce torpedoes capable of a much higher velocity than has been so far attained.

Even supposing the upper curve in the Plate be not such as is anticipated, it is evident from its general direction that it will not be likely to intersect the ordinate of twenty knots at a point higher than that intersected by the tangent shown by the dotted line. This would indicate that a pull of 60.5 pounds would drag the torpedo at the rate of twenty knots per hour, but to allow an ample margin I have assumed that the pull will be 100 pounds, and on this supposition, together with the fact that at the rate of nine statute miles per hour, the pull was 38 pounds, I have made the following calculations with propellers of coarse and fine pitch :

Three-cylinder Brotherhood engine—diameter of cylinder=2 in. with, 2 in. stroke.

To drive the fish at the rate of 20 knots per hour, the pull being assumed as 100 lbs., the engine must work to 6.14 H. P. At a pressure of 60 lbs. per sq. in. the engine will give 188.496 foot pounds per revolution; hence 1,075 revolutions must be made per minute, and the pitch of the screw is 1.8 ft.; the pitch being so small, (comparatively,) we will allow three-fourths of the number of revolutions for slip, friction, &c., which gives 1,881 revolutions to be made per minute. The torpedo being at a depth of 8 feet below the surface, the actual pressure delivered by the reducer to the engine must be 63.56 lbs. to obtain a pressure equal to what 60 lbs. per sq. in. would give were the engine working in the air. The air chamber or reservoir, containing 4.303 cu. ft., will hold 258.18 cu. ft. of air at a pressure of 900 lbs. per sq. in.; the reducer, however, being set to deliver at 63.56 lbs. per sq. in., the engine will only maintain its constant speed until the pressure in the reservoir is reduced to that amount; this will deduct 18.2 cu. ft. from the contents of the reservoir, leaving 239.98 cu. ft. available. Since there are three cylinders to the engine, and it is working at a pressure of 4.23 atmospheres, there will be consumed 159.467 cu. in. at every revolution and 299,957.42 cu. in. per minute. The torpedo should,

therefore, run for 1.3 minutes, or about 2,600 feet, at the rate of 20 knots per hour.

To drive the fish at the rate of 9 statute miles per hour, (short 8 knots,) the pull being actually 38 lbs., the engine must work to .912 H. P. With the same screw 440 turns must be made per minute, developing 65.37 foot pounds per revolution; hence the reducer must be set to deliver at 24.56 lbs. to give the effective pressure of 21 lbs. per sq. in., which is required. This deducts 7.01 cu. ft. from the contents of the air reservoir, leaving 251.17 cu. ft. available. Three cylinders, at 1.63 atmospheres, will consume 61.449 cu. in. at each revolution; and since, by allowing three-fourths of the number of revolutions for slip, &c., as in the preceding case, there will be 770 revolutions to be made per minute, the air consumed in that time will be 47,315.73 cu. in. The torpedo should, therefore, run for 9.3 minutes, or about 1.2 knots, at the rate of 9 statute miles per hour.

Suppose, however, that instead of supplying air to the engine at as low a pressure as 60 lbs. per sq. in., it be supplied at a pressure of 300 lbs. per sq. in., the engine will then give 942.48 foot pounds per revolution; hence 215 revolutions must be made per minute and pitch of screw is 9.45 feet, the pitch being so large, we will only allow one-fourth of the number of revolutions for slips, &c., &c., which gives 269 revolutions to be made per minute. The reducer must be set at 303.56 lbs., which gives 87.04 cu. ft. to be deducted from contents of air chamber, leaving 171.14 cu. ft. available. Three cylinders, working at a pressure of 20.23 atmospheres, will consume 762.654 cu. in. at each revolution and 205,153.9 cu. in. per minute. The torpedo should, therefore, run for 1.4 minutes at the rate of 20 knots per hour or about 2,800 ft.

To drive the fish at the rate of 9 statute miles per hour with this propeller, 84.2 turns must be made per minute, developing 341.6 foot pounds per revolution; hence reducer must be set to deliver at 112.26 lbs. to give an effective pressure of 108.7 lbs. per sq. in., which deducts 32.18 cu. ft. from contents of air reservoir, leaving 226. cu. ft. available. Three cylinders, at 7.48 atmospheres pressure, will consume 281.99 cu. in. per revolution; and since, by allowing one-fourth of the number of revolutions for slip, friction, &c., as in the preceding case, there will be 105.2 revolutions to be made per minute, the air consumed in that time will be 29,665.32

cu. in. The torpedo should, therefore, run for 13.2 minutes, or 1.7 knots, at the rate of 9 statute miles per hour.

It would appear from the foregoing calculations that the question of speed with the fish torpedo depends very much on the propeller, since the Brotherhood engine is capable of either making a very great number of revolutions per minute or of working at a very high pressure. As before stated, the propeller used by Mr. Whitehead has never been described except as regards the number of its blades, and it may be either very great in diameter with large "clover leaf" blades of very coarse pitch and joined to the hub by slender wrists, or it may be of smaller diameter with a large hub and blades narrow at the point and tolerably broad near the hub with a comparatively fine pitch. The circumstances will admit of the application of either screw, since the torpedo is wholly immersed and has a very clean run. The former propeller, however, would seem to present so much surface that the loss from skin friction would more than counterbalance the gains from the small slip; and it seems plausible to suppose that a smaller propeller, made as described and having a keen cutting edge, with its whole surface highly polished, would give the best results, (although the amount of friction of working parts inside the torpedo would be in favor of the former,) since it will work at a depth such that the supply of water to it will be solid and continuous and a large percentage of slip may be allowed, while the loss from skin friction would be small.

To determine practically the best propeller for the purpose, I would propose to make several of different dimensions, to be tried in a large box of water provided with a stand pipe, eight feet high, to give the required pressure. A shaft should pass through one side of this box and the propeller be connected with it by means of a sliding clutch or sleeve, so that the propeller is free to revolve with the shaft and at the same time to move along it. The rear end of the clutch or sleeve passes through the opposite side of the box and is connected to a spring scales. The shaft being driven by belting or gears at any required velocity, the pointer of the scales would show the pull exerted by the propeller. A choice could thus be made, with very little trouble, of a few propellers which would pull 100 lbs. with less expenditure of power, disturbance of water, &c., &c., than the remainder, and a choice between these few could be made by connecting the shaft of the fish itself to the shaft in the

box and running its engine with its own charge of compressed air, having the exhaust fitted with a valve and weighted to correspond to a depth of 8 feet. The propeller which, under these circumstances, pulled 100 lbs. for the greatest length of time would give the greatest range to the torpedo at the required speed, although it is possible that exactly accurate results might not be obtained on account of the motion of the water in the box and the fact of the engine not being surrounded by water.

The discussion of the propeller would seem to conclude every detail with regard to the construction of a fish torpedo, and it only remains to observe that the mechanical workmanship displayed in the construction of the Whitehead is said to be extraordinarily fine though it would seem to be absolutely necessary that it should be so in order to insure success.*

To the individual with few mechanical ideas, the performance of

* November 28.—The latest official information concerning the 17 knot Whitehead is an article which appears in the Army and Navy Journal of this date. It is to the effect that a number of trials had been witnessed at Fiume by the officers of the U. S. S. Juniata, who report that "The torpedo is cigar-shape made of one-eighth inch steel, nineteen feet long, the greatest diameter being fifteen inches. The propeller is six-bladed, ten inches in diameter, with expanding pitch. The torpedo has four T angle pieces running about three-fifths of its length, which are used for resting the torpedo in launching. At the point or bow a small pistol is attached which is fired by concussion. It is very sharp forward, and it is exploded by striking an object with its sharp spur or by three triggers, which are placed one above and one on each side of the spur, coming in contact with the side or bottom of a ship. The explosive chamber will contain 66 pounds of powder. The torpedo has no steering apparatus, and can consequently travel only in the direction given it by the directing ship at starting, but when once discharged from the tube there is no deviation. The velocity being measured by space passed over was found to be for 600 feet seventeen knots, with a pressure of 1,000 pounds per square inch." These statements, like those in most other accounts, evidently combine facts and fancies, but if the dimensions of the torpedo be correct as given, it would appear that Mr. Whitehead is endeavoring to attain his high velocities by means of a small screw of many blades, driving a vessel whose length is excessive as compared with its diameter, and whose sharpness is very great. The displacement will be found by calculation to be only about 100 pounds greater than that of our proposed torpedo, (though it is about $6\frac{1}{2}$ feet longer,) on account of its smaller diameter, and it can consequently be said to be but little larger. Moreover, this extra amount of displacement is most likely entirely consumed in the increased weight required for the shell, while the amount of "wetted surface" is very much greater than in ours, and the very long sharp bow brings into consideration the question of how far it is safe to carry the centre of the explosive charge away from the enemy's vessel, with whose side the bow may be in contact.

the Whitehead torpedo seems almost miraculous, while to the ingenious, though unthinking mechanician, it may seem easy of construction, if only a skillful mind be brought to bear upon the subject. That its performance is not miraculous has, I hope, been shown, but that it is an easy problem for solution is far from being the case. "There is an obstinacy in inanimate objects which only perseverance can overcome," and the best digested plans on paper will seldom work with facility till many trials have removed all slight causes of disarrangement which will occur, the evils being especially aggravating when the apparatus is under water and no one there to see what particular member has refused to function, and thus caused the failure of the whole. Again, it would seem that in this case at least the merit of the invention lies to a great extent in the idea, and not wholly in the manner of carrying it out. No one before Mr. Whitehead had, to my knowledge, even proposed accomplishing what he has, and had it not been known that he had produced such a projectile torpedo it seems hardly probable that we would be considering attempts in that direction on his method even now.

LATEST.

FIUME, AUSTRIA, Jan. 6, 1875.

Commodore WM. N. JEFFERS, U. S. Navy,
Chief of Bureau of Ordnance,
Navy Department, Washington, D. C.

SIR: Although I am aware that the Whitehead Fish Torpedo has been quite recently reported upon by Commanders Braine and Kirkland, still, learning that new points were being developed, I have considered that a letter to the Bureau on the subject would not be uninteresting.

The German Government has ordered from the Messrs. Whitehead & Co. 100 of the latest improved torpedoes, and has advanced funds for the establishment of a regular torpedo factory.

The French Government has ordered 50.

In addition to those already known to the Bureau, the subject is being considered by the Governments of Russia, Denmark, and Belgium.

I arrived in Fiume on the 4th instant, and the following day had a long conversation with Messrs. Whitehead and Hoyos.

It is claimed by the owners at present that this torpedo—

(1) With a starting speed of 18 knots per hour, will maintain this rate and given submersion for the distance of 600 feet, after which, speed, and consequently accuracy, will gradually diminish until the distance of about 2,600 feet from the starting point is reached, when it will rise to the surface.

(2) With a starting speed of 15 knots, the rate remains constant for the distance of 1,800 feet, extreme range 4,000 feet.

(3) With a starting speed of 12 knots, rate remains constant for the distance of 3,500 feet, extreme range 5,000 feet.

(4) With a starting speed of 9 knots, this rate will remain constant for the distance of 6,000 feet, extreme range probably only slightly greater.

(5) With a starting speed of 5 knots, a range of from 12,000 to 15,000 feet may be anticipated. The speed, submersion, and distance run within limits can be regulated at pleasure.

The owners admit that the accuracy rapidly diminishes after the speed decreases below 8 knots.

On being questioned as to the probable performance where much grass or sea-weed was growing, they seemed doubtful as to the effectiveness, but suggested fitting an iron or steel frame around the propellor. With the new model, the ring guard over the latter has been abandoned. In sending the torpedo through grass and sea-weed the cross triggers would have to be dispensed with, and the bursting charge fired by the impact of the point alone. The cap would probably explode in all cases where the blow was struck at a greater angle than 10° degrees.

The presence of mud does not appear to have ever been detrimental to a good performance.

On being asked for information concerning the action of currents and tides, they referred me to the results of the trials at Venice, Rochefort, in the Medway, the Scheldt, and at Bremen-Hafen, where the strength of the tide varies from 2 to 4 knots, which appear to have been quite successful.

The following experiments were made to-day: Dimensions of torpedo—length, 5 meters; greatest diameter, 445 millimeters; weight, including charge, 341 kilograms.

Submersion, 5 feet.

1st shot. Torpedo arranged to rise at the distance of 600 feet. Speed obtained, 15 knots. Accuracy, very good.

2d shot. Torpedo recharged and arranged to rise at 600 feet. Speed obtained, 16 knots. Accuracy, very good.

3d shot. Torpedo recharged and arranged to rise at 1,000 feet. Speed obtained, 14 knots. Accuracy, very good.

4th shot. Torpedo fired from buoy, without recharging; arranged to rise at 1,000 feet. Accuracy, good. Speed obtained, 12 knots.

5th shot. Torpedo started from boat without recharging, in order to ascertain how much force remained. The torpedo raised at about 600 feet distance. Speed averaged, 5 knots. Accuracy, very poor.

6th shot. Torpedo arranged to rise at 600 feet, in order to test the adjustment of the rudder for the succeeding shot, which I had requested to be fired to indicate the greatest range at the lowest steering speed. Speed obtained, as desired, 9.5 knots. Accuracy, good.

7th shot. Fired for the above mentioned purpose. The result was a failure. The torpedo started seawards and then turned in a circle. A satisfactory reason was not given.

8th shot. Torpedo recharged and fired as before. Speed as desired, about 9.5 knots. Accuracy: at 3,000 feet there was a divergence of about 50 feet; at 4,500 feet, the greatest range obtained, this divergence had materially increased.

The experiment with the submerged screen or netting to illustrate the fact that the torpedo preserves its depth was dispensed with, as having been thoroughly established in trials previously reported to the Bureau.

I would respectfully call the Bureau's attention to the fact that a trial shot, No. 6, was deemed necessary before venturing upon the long range firing, and observe, in addition, that during the whole day's work the greater part of the precautions taken referred to the adjustment of the steering apparatus; this under the most favorable circumstances possible.

From the results obtained to-day, it appears that for short distances in water free from grass or sea weed, either still or where the force of the current can be considered constant, the fish torpedo is a valuable and effective means of defense. But where the distances are greater, say than 2,000 or 3,000 feet, where the currents are indefinite or variable, where its passage

may be obstructed by sea weed or river grass, a great inaccuracy may be feared.

A very slight action upon the rudder affects the course of the torpedo very materially.

Messrs. Whitehead & Co. are at present employed upon the development of an idea suggested by the Belgian government; i. e., the construction of a fixed torpedo, which shall, in the rise and fall of a tideway, preserve a constant submersion. This, they inform me, approaches successful completion, but that since in its construction some of the important points of the movable torpedo still secret are employed; the acquisition of the fixed torpedo by a foreign Government will entail the purchase of the other also.

I believe the Bureau to be already in possession of the terms on which the torpedo company will sell.

I remain, sir, very respectfully, your obedient servant,

W. M. FOLGER, *Lt. Commander.*

APPENDIX.

Extracts from Report of Austrian Commission on the trials of the Whitehead Torpedo in 1868.

According to the wishes of the inventor, the launching tube should be 12 feet below the surface of the water; but with the 'Gemse,' a third-class gunboat with a draught of $7\frac{1}{2}$ feet forward and 9 feet aft, only an immersion of 3 feet could be obtained, and it was therefore necessary that the torpedo should seek its own level at any depth that might be required. The commission had at their disposition two torpedoes, the smaller one adapted to the diameter of the tube fixed in the 'Gemse,' and a larger one, the normal torpedo, so-called from its dimensions corresponding to a charge of 60 lbs. of gun cotton. A quantity of junk equal to the explosive charge in weight was placed in each torpedo.

The experiments were commenced with the small torpedo. The yacht 'Fantasie' was moored with her broadside towards the bow of the 'Gemse,' to serve as a target. Along her own length and that of a boat behind her poop, was hung on outriggers a spun-yarn netting 18 Vienna feet* in width.

*1 Vienna foot = 12.45 U. S. inches.

This was lowered to 6 feet below the surface, and to the foot rope were attached heavy stones to keep it straight. Prepared in this way, the target measured 200 feet in length and 24 in width, Plate X. According to the contract, the best hits were to be those which struck within a rectangular space of 3 feet deep and 24 feet long. This rectangle was $10\frac{1}{2}$ feet below the surface, and the middle of it, or 12 feet, was the depth for which the torpedo was regulated. Not to lose too much time in shifting the moorings of the 'Gemse,' in order to aim at the central line of the 'Fantasie,' the side of the latter was divided by a number of white vertical stripes 10 feet apart, and the stripe to which the 'Gemse' was directed at the moment of launching was taken as the central line—the distance between the ships was 2,000 Vienna feet.

After 54 experiments the trials were suspended for a time, as the oscillations of the torpedo were so great that it varied from 8 to 40 feet in depth, while sometimes it rose to the surface, and sometimes remained fast in the mud at the bottom. Only 8 times the torpedo was caught in the net; 16 other times it passed through below the netting; therefore, supposing the oscillations to have been avoidable, not quite half of the shots would have hit a ship 200 feet in length. The mean velocity was 9.43 feet per second. For three weeks after these trials no further experiments were made, during which time the inventor added an improvement, by means of which he

hoped to prevent the oscillations. After the improvement had been added, a second series of trials was made, during which the torpedo kept a level course and attained a velocity of 9.76 feet per second. A few irregularities which occurred towards the end of the series was caused partly by small imperfections (which were afterwards easily remedied), and partly by putting the torpedo into its floating wooden box, which was done from a boat after each trial, the waves rendering it difficult in this operation to avoid either bending or changing the steering apparatus. The certainty of hitting was much increased in the second series of trials, as 50 per cent. now remained in the netting, and two other times (Nos. 1 and 9) the torpedo just grazed it.

Table of Second Series of Trials.

No.	No. in list of all trials.	Deviation.		Depth	Velocity in ft. per second.	Remarks.
		Right.	Left.			
1	55	.....	94	11	11.76	Grazed the net under the bow.
2	56	.....	160	.....	11.24	
3	57	240	.....	.....	11.49	
4	58	cen tre	.....	11	11.11	Net.
5	59	cen tre	.....	10	10.99	"
6	60	.....	170	.....	10.87	
7	61	.....	140	.....	8.63	
8	62	.....	240	.....	8.00	
9	63	.....	92	10	8.51	
10	64	stuck	in the ground.			
11	65	.....	10	12	9.09	Net.
12	66	20	.....	19	8.95	"
13	67	120	.....	12	8.57	
14	68	69	.....	10	9.23	Net.
15	69	.....	68	12	8.95	"
16	70	.....	44	11	9.02	"
17	71	22	.....	11	9.09	"
18	72	.....	18	11	9.02	"
19	73	80	.....	15	9.09	"
20	74	.....	130	.....	8.82	"
21	75	.....	28	12	9.02	"
22	76	.....	72	12	9.99	"
23	77	.....	.....	.....	.....	Stuck in ground 250 ft. from
24	78	80	.....	13	10.57	Net. [Gemse.
25	79	500	.....	.....	.....	Stuck in ground on shore.
26	80	.....	25	12	11.90	Net.
27	81	60	.....	11	11.56	"
28	82	500	.....	.....	8.37	Uncertain.
29	83	.....	140	.....	9.50	
30	84	.....	200	.....	10.00	

In order to prove whether the pneumatic apparatus was sufficient to send the torpedo out from the tube when the ship was in motion, several trials were made with the 'Gemse,' moving at about 7 knots; the torpedo came out without any apparent difficulty; it was only necessary not to overrun it, nor, while keeping a parallel course, to turn it from its direction by the force of water thrown aside by the ship. Immediately after launching it was necessary either to ease the engine or put the helm hard over either way. Several trials with the ship moving astern showed that the eddy had no influence on the direction of the torpedo. Trials were also made with both ships in motion. They proved, as was expected, that it is very difficult, and requires great practice and correctness of eye, to hit any ship whose course crosses that of the torpedo ship at about right angles.

For the trials with the 'normal torpedo,' the temporary launching tube was fixed to four wooden guides or hangers, which were passed through iron clamps in each side of the bowsprit of the 'Gemse,' and could be moved up or down at pleasure, so that the torpedo, when filled, could be lowered to the required depth. This arrangement proved unsatisfactory, on account of the impossibility of preventing the tube from swaying to and fro with the least rolling motion of the ship, so that the aim always became uncertain. An iron horse was now constructed and placed in position at the bottom of the harbor, and upon this the launching tube was laid at a depth of 14 feet below the surface, the torpedo being regulated to remain at that depth throughout its course. Several trials were made with the results shown in the plate. The mean velocity was 11.17 feet per second.

The trials made proved that the greatest distance run was 4,000 feet, and that the torpedo maintained its direction up to 2,000 feet; but after that distance the course slightly deviated in consequence of diminished speed. During the trials on several occasions the capsule for firing the explosive charge was put on, and it was seen that even the slightest touching of the netting was sufficient to fire it off. It was ascertained also that 5° from the axis of the torpedo was the smallest angle at which the point could touch an object, and at this angle the explosion was certain.

To prove how well the torpedo answered its helm, the inventor launched it from a boat, fixing the rudder to the starboard side about half an inch from the center line, and launching it by hand from near the surface of the water. The torpedo described three times exactly the same circle of about 480 Vienna feet in diameter.

The summing up of the different trials gave the following points as the opinion of the commission—

- 1st. The exploding power of 40 lbs. of gun cotton is quite sufficient to sink any ship.
- 2d. The certainty of hitting is as great as can be expected from such an arm.
- 3d. The apparatus for firing never fails.
- 4th. The velocity is indeed not great enough to catch a fast-going

ship in a chase; but it is quite sufficient for the defense of harbor entrances, and for the attack of ships at anchor; and as ramming is now the principal mode of attack in naval battles, and they therefore become nothing short of a *mêlée*, torpedoes can even then be employed with great advantage.

The commission therefore voted unanimously for the acquisition of the secret. The shots in the plate are noted as follows:

- First series of experiments of 54 shots, only 8 caught in the net.
- Launching vessel 'Gemse' in motion, and the 'Fantasie' moored. Of six shots, 2 in net.
- ◉ Launching vessel 'Gemse' going backwards. 'Fantasie' moored. Small experimental torpedo used.
- ◐ Second series of experiments with small torpedo arranged with Mr. Whitehead's improvements. Of 30 shots, 15 in net.
- ◑ With large 60 lb. charge torpedo, both vessels moored.

Description of Electrical Apparatus for Steering the Station fish Torpedo. Plate XI. Figs. 1 and 2. [Omitted.]

The arrangement consists of a compass, E, a small battery, F, and an electro-magnet clutch, B, connecting with a rod, C, which works the yoke of the rudder S.

The compass card is an ordinary double barred one, to which is secured a "course indicator" (shown in black) consisting of a light bar of brass secured to the compass card in the center with sufficient tightness to hold it by mere friction on any point of the card to which it may be turned. The center of this bar is solid, but capped out on the under side to receive the point of the pivot. The spindle or pivot is to be entirely of brass, and insulated from the compass bowl as shown. In its base is a screw cup for securing one of the wires from the battery; the bowl is hung in gimbals, as usual, and at the rear side are two brass pins, *xx*, with screw cups for attaching insulated wires which lead to the magnet clutch, as shown.

The battery consists of a suitable cell hung in gimbals; one of its poles is connected by a wire to the screw cup in the base of the compass pivot, while the other is connected to the shell of the torpedo as an earth.

The magnet clutch consists of a sleeve, B, fitting loosely on the shaft, to the side of which are attached a beam, *b*, and two electro-magnets, *yy*. The beam *b* pivots horizontally about the point *v*, and its ends are provided with right and left scores to correspond with the right and left screws on the por-

tions of the shaft immediately opposite them. *ll* are small spiral springs which tend to restore the beam to the position shown if moved out of that position; the arm by which the beam *b* is connected with the sleeve, is prolonged beyond it far enough to be connected to the rod C, which communicates motion to the rudder yoke by means of a pin and slot. The rod C is supported at its forward end by a bearing, D, on each side of which it is surrounded by a spiral spring, as shown—the office of these springs being to bring the helm amidships whenever the beam *b* is detached from contact with either screw on the shaft. The electro-magnets on the sleeve are connected by means of insulated wires with the pins *xx* on the compass bowl, as shown in Fig. 1, and also with the shell of the torpedo for an earth, as shown in Fig. 2.

The apparatus functions as follows: Wishing to steer a due *east* course, the "course indicator" is turned on the card so that it lies over the east and west points. This brings it into the position shown in the plate, viz., with the rear end of the "course indicator" midway between the pins *xx*, and with the beam of the magnet clutch in a neutral position; the torpedo must then run on an east course, for a slight deviation either way brings the "course indicator" in contact with one or the other of the pins *xx*; an electric current is immediately established from the battery, through the compass-card pivot, the "course indicator," the pin *x* and its connecting wire, round the coils of the corresponding electro-magnet, to the shell of the torpedo, and back again to the battery; the effect of this current is to put in action the electro-magnet, through whose coils it is passing, thereby tilting the beam, to which is attached its armature; the tilting of the beam brings its end in contact with the corresponding screw on the rapidly revolving shaft, which causes the whole clutch to take up a movement along the shaft, dragging the rudder yoke with it by means of the rod C; the helm being thus put over, is kept there until the torpedo heads in the proper direction, since the beam soon runs itself off the screw thread on the shaft, and the sleeve remains stationary in the new position; as soon, however, as the torpedo is on the right course, the compass card swings so as to bring the "course indicator" away from the pin against which it was pressing, which breaks the current and demagnetizes the electro-magnet. The springs *ll* bring the beam into its neutral position, and the springs at D being free to act, bring the helm amidships.

The contact of the "course indicator" with the other pin, *x*, causes the exactly opposite effects to those described, by putting the other electro-magnet into action, which, by attracting the other end of the beam, causes the clutch to move the other way, and reverses the helm.

THE LUPPIS-WHITEHEAD OR FISH TORPEDO.

PLATE I

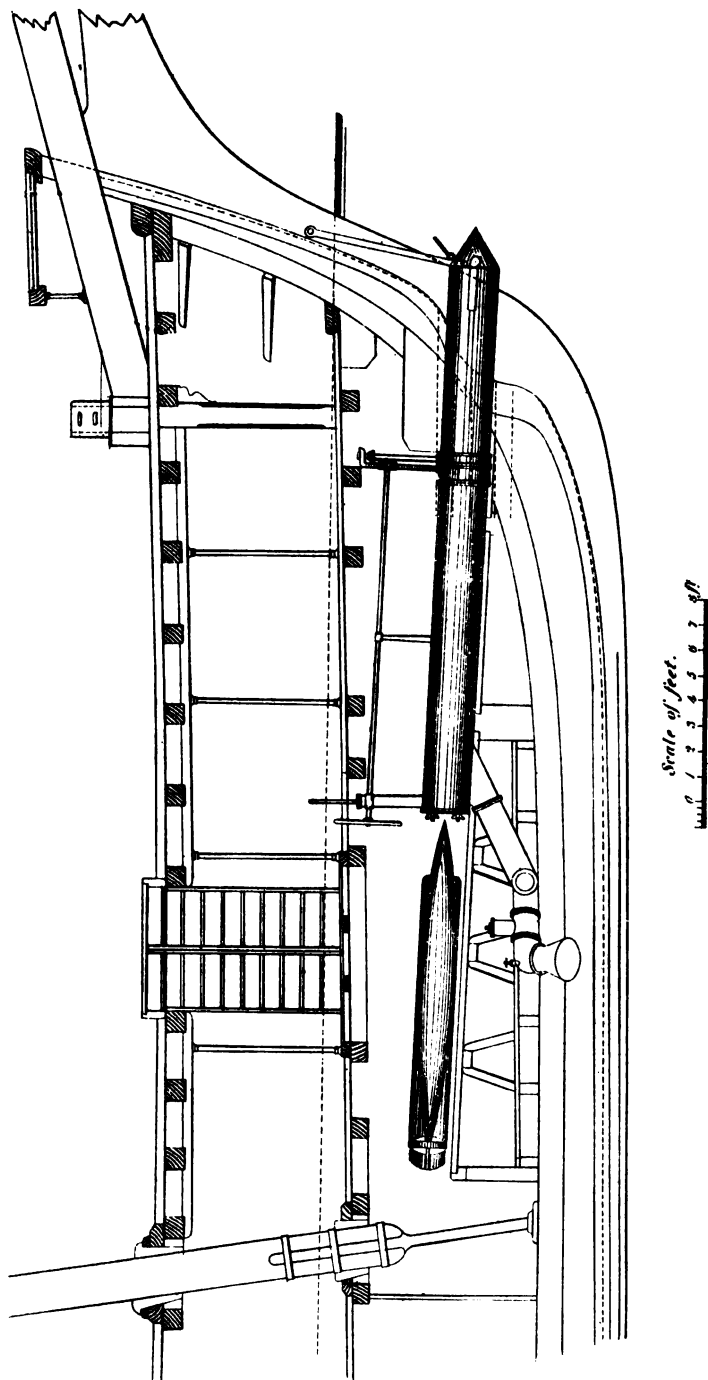
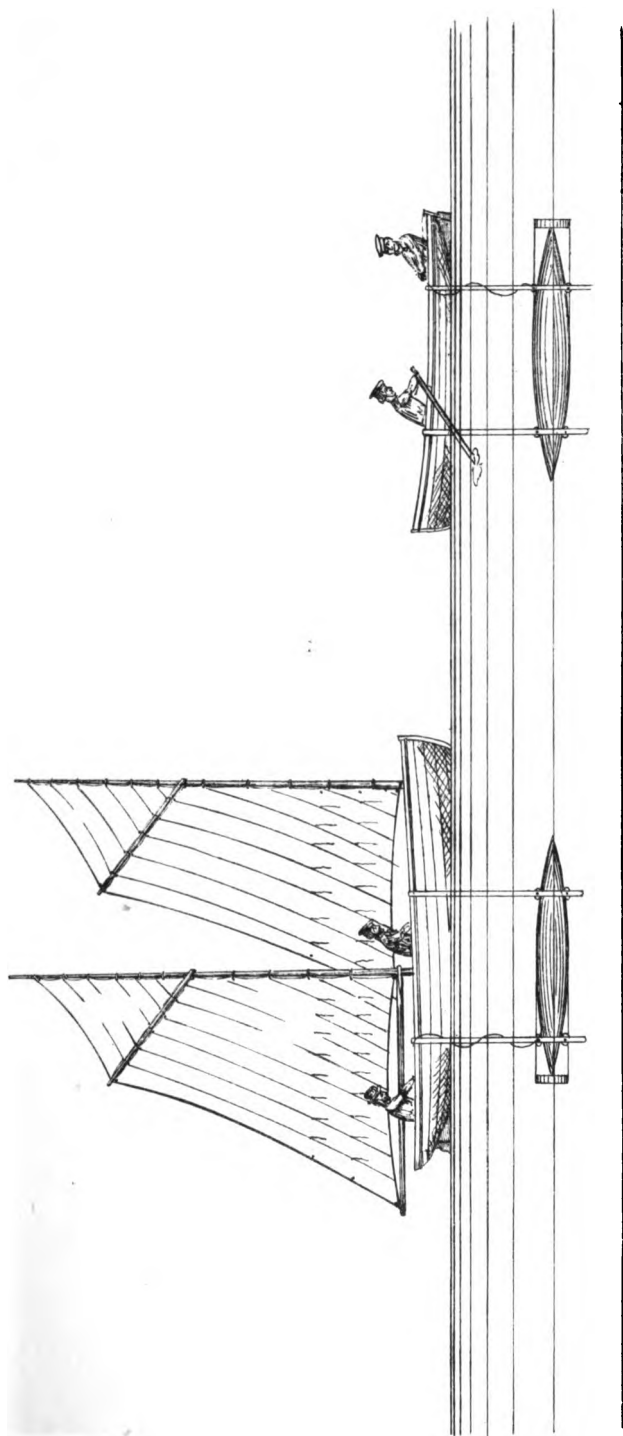


Plate III.



H. PETER, PHOTO-LITHOGRAPHE, WASHINGTON, D. C.

Plate v.

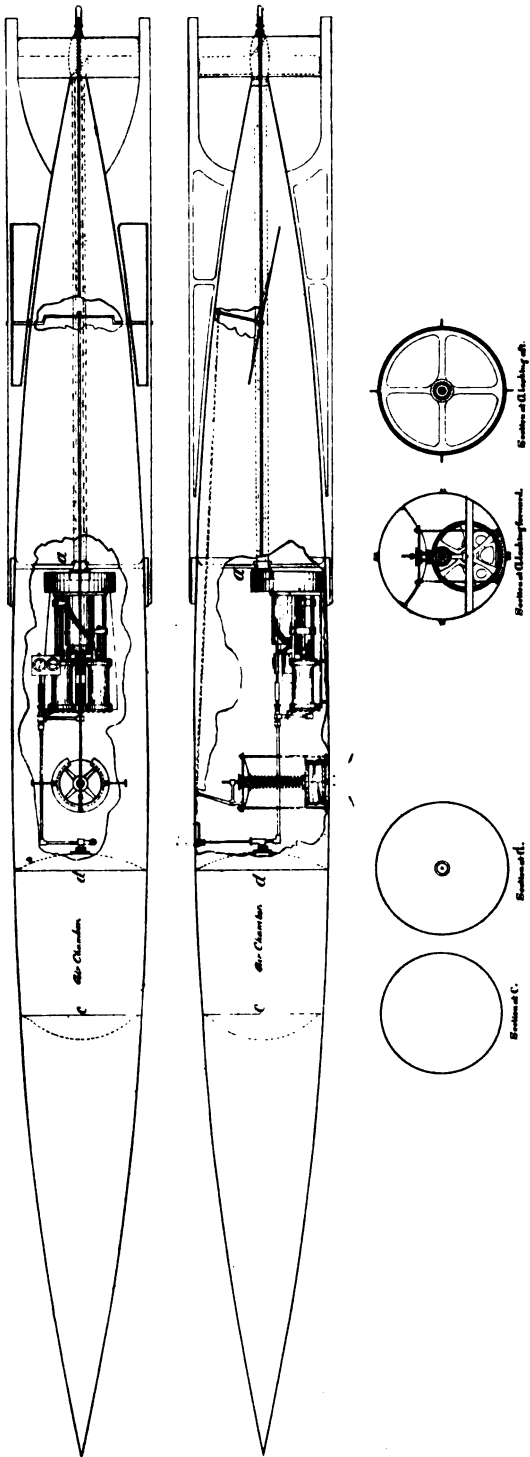
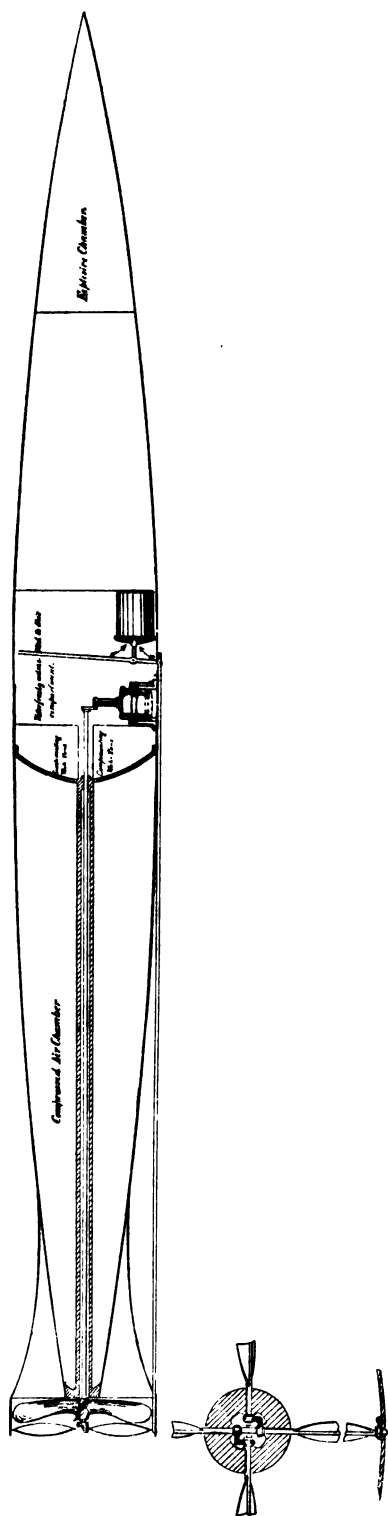
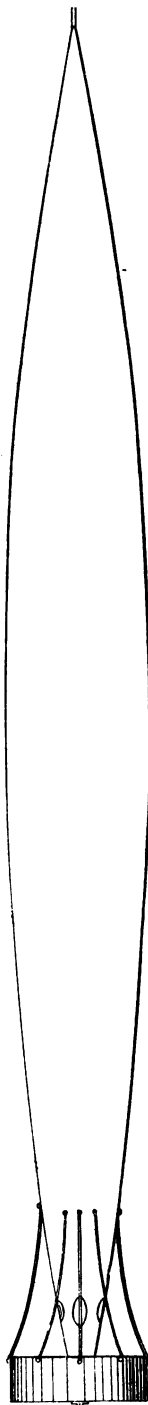


Plate VI.



PLANS FOR A FISH TORPEDO
U. S. TORPEDO STATION
JUNE 1st 1874.

EXTERIOR VIEW.



INTERNAL ARRANGEMENT WITH COMPRESSED AIR FOR MOTIVE POWER.

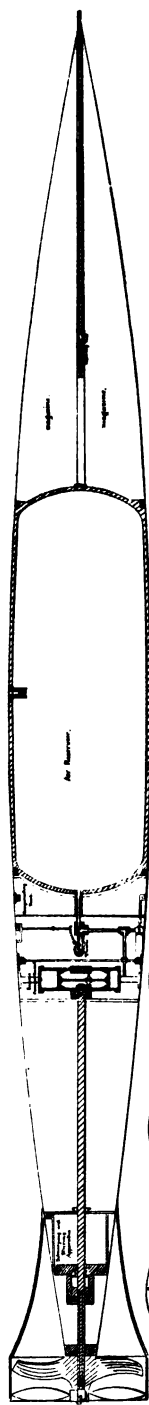
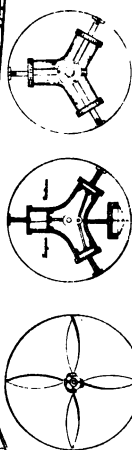


Fig. 1



INTERNAL ARRANGEMENT WITH CARBONIC ACID GAS FOR MOTIVE POWER.



Fig. 2

Plate X.

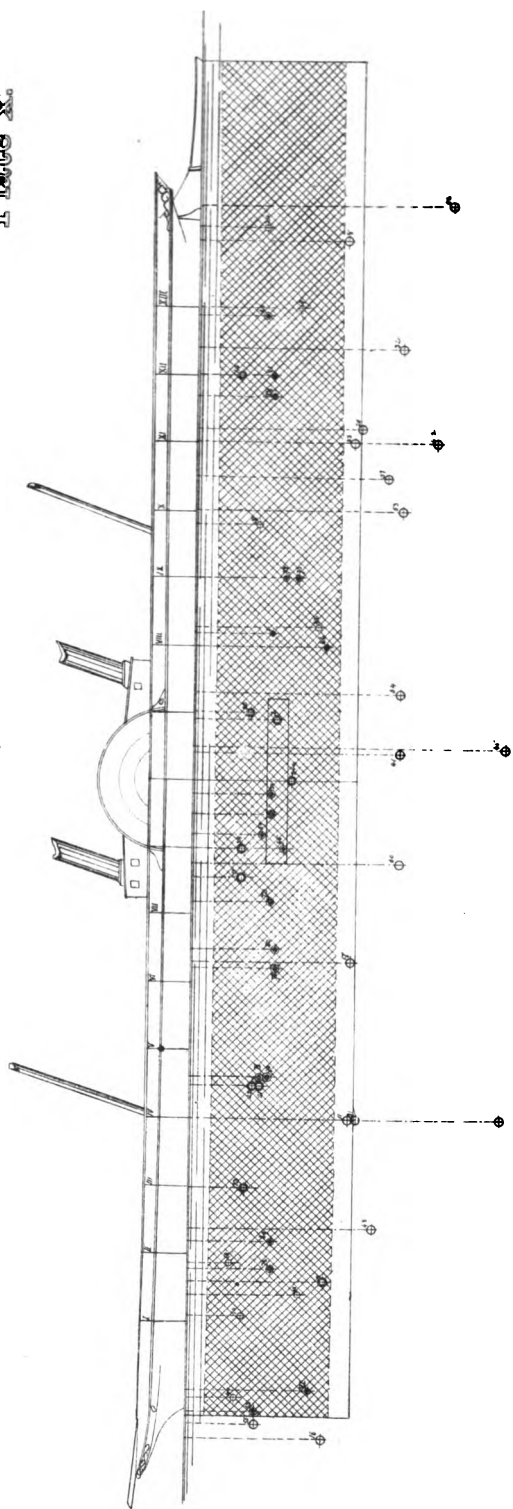


Fig. 1

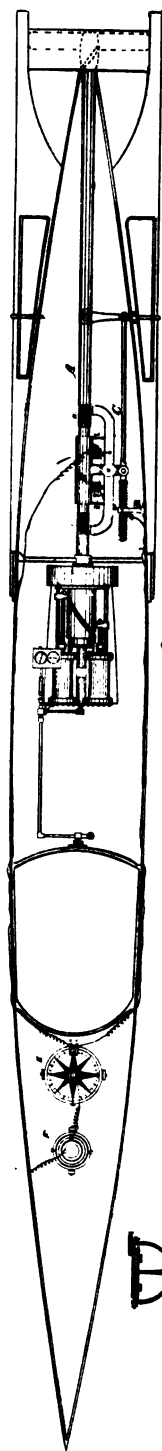
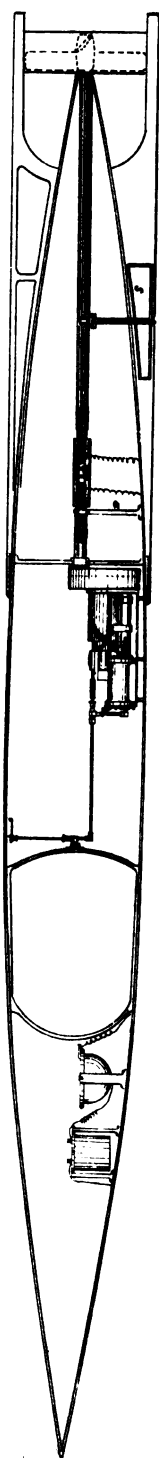


Fig. 2



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